NSMB results for the 2nd High Lift Prediction Workshop

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Outline

- Introduction
  - Motivations
  - NSMB CFD solver
  - Test cases performed
- Results
  - steady simulations
  - unsteady simulations
- Conclusions

Motivations

- to obtain better understanding of the physics of high lift flows
- to better understand the difficulties in simulating high lift flows
- to test our CFD code
- to obtain results for chimera validation

CFD solver : NSMB (Navier-Stokes Multi-Block)

History :

- In 1992, NSMB is developped in an international consortium with industrial partners (Airbus & SAAB Military Aircraft, CFS Engineering) and academic partners in France, Germany and Switzerland (EPFL, SERAM, IMFT, KTH, CERFACS)
- Today, it is developped by EPFL, ETH, Icube, IMFT, TUM, Polytechnique Montreal, CFS Engineering and RUAG and NSMB is being used by Airbus-France, EADS-ST and KTH

Descriptions :

- Finite volume Navier-Stokes solver with multi-blocks definition
- Wide code based on general features of modern CFD (grid flexibility, space discretization schemes, time integration, convergence acceleration, parallel computing, ...)

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Test case performed :

Case 1, configuration 2

Configuration :
DLR-F11 in landing configuration
slat 26.5 deg, flap 32 deg without bracket

Flow parameters :

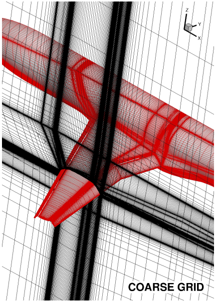
Mach	=	0.175
Angles-of-attack	=	7, 16, (22.4) deg
Reynolds number	=	15.1 million based on MAC
Ref. Static Temperature	=	114.0 K
Ref. Static Pressure	=	295000 Pa
Fully turbulent		

Meshes :

Committee-supplied structured 1-to-1 grids :
A_str_1to1_Case1Config2

3 grid sizes :

	cells	dy [mm]	dy / MAC
coarse	9,556,725	0.0006525	1.88e-6
medium	31,998,440	0.000435	1.29e-6
fine	100,561,536	0.00029	0.83e-6



Reference :

$$C_{ref} = MAC = 347.09\text{mm}$$
$$S_{ref} = 419{,}130\text{mm}^2$$
$$(x, y, z)_{ref} = (1428.90\ ,\ 0.0\ ,\ -41.61\ )\text{mm}$$

Parameters of simulations

All calculations were made using the following parameters :

- Space discretization :
  4th order central scheme with artificial dissipation (JST)
- Time integration :
  implicit 2nd order backward, LU-SGS
  - steady : local time step, no multigrid
  - unsteady : dual time stepping ($\Delta t = 0.005$), multigrid
- Turbulence models :
  SA, SA Edwards, SA-salsa

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List of simulations

- Steady (27 simulations) :

Grid	coarse			medium			fine		
Angles (deg)	7	16	22.4	7	16	22.4	7	16	22.4
SA	x	x	x	x	x	x	x	x	x
SA-salsa	x	x	x	x	x	x	x	x	x
SA-Edwards	x	x	x	x	x	x	x	x	x

- Unsteady (7 simulations) :

Grid	coarse			medium			fine		
Angles (deg)	7	16	22.4	7	16	22.4	7	16	22.4
SA				x					
SA-salsa				x	x	x			
SA-Edwards				x	x	x			

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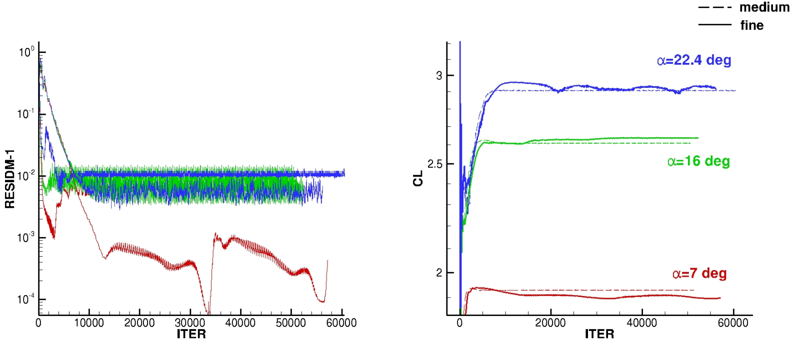
Convergence of simulation



(SA-Edwards)

Each simulation $NITER > 50,000$
Average performed after $NITER = 25,000$

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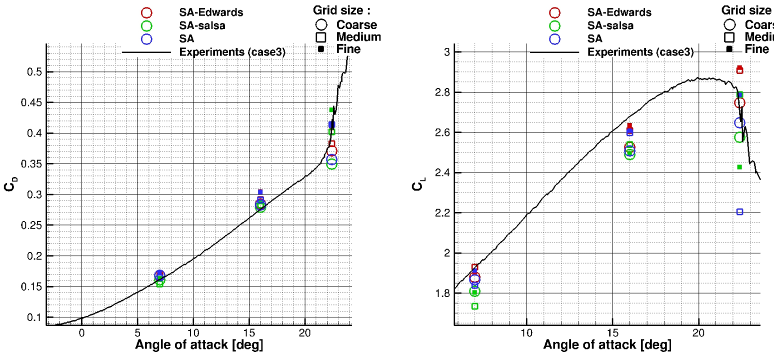
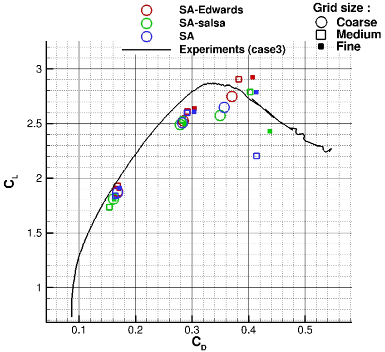
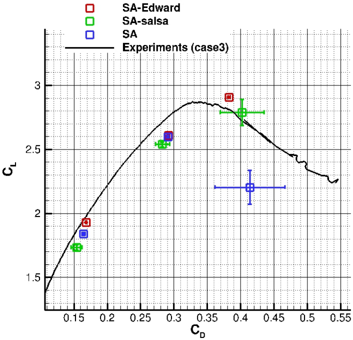
Drag and Lift coefficients versus angle of attack



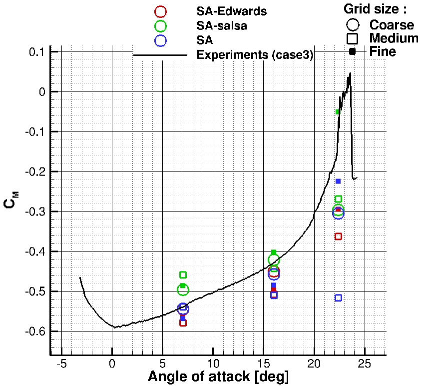
Drag and Lift coefficients : polar representation



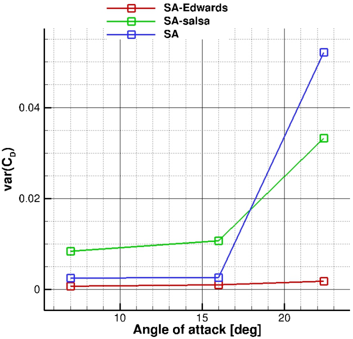


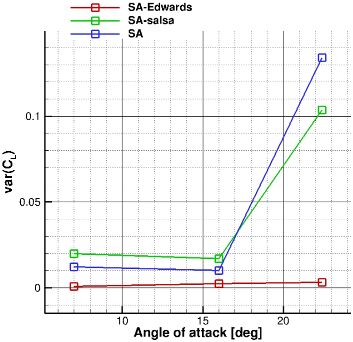
(Medium grid)

Pitching moment coefficient

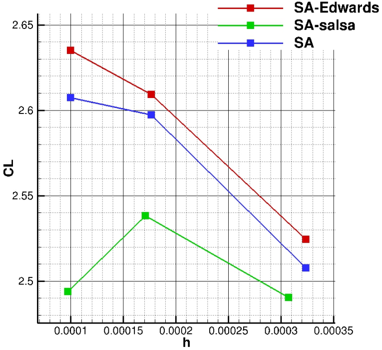


Variation of coefficients (on medium grid)

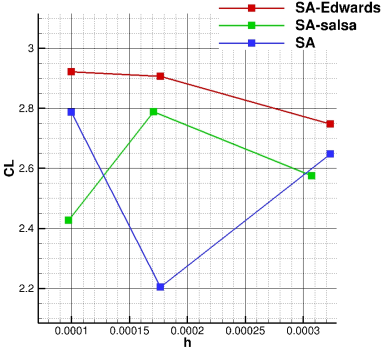




Mesh convergence

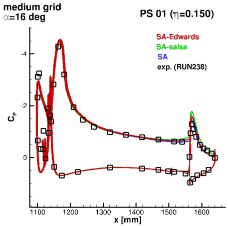


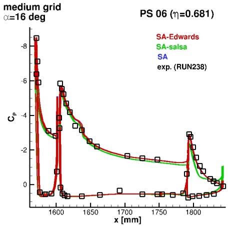
$\alpha = 16[deg]$

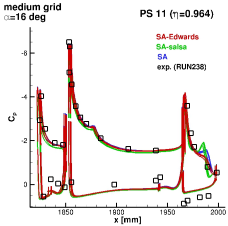


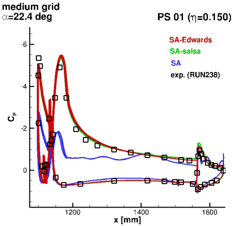
$\alpha = 22.4[deg]$

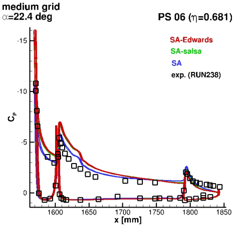
Pressure distribution

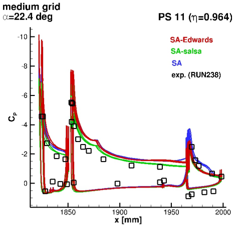




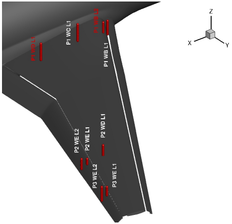




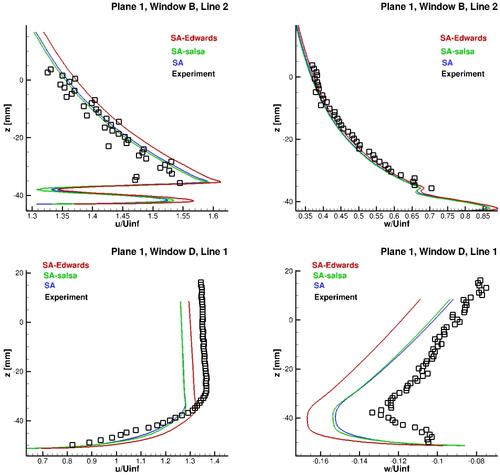




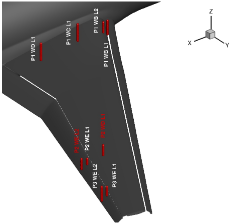
Velocity along the vertical lines



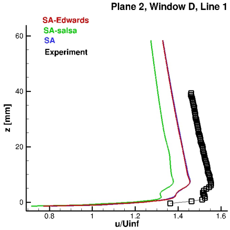
$alpha = 7deg$

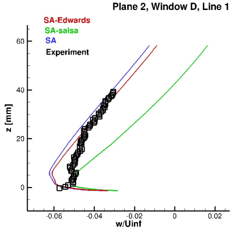


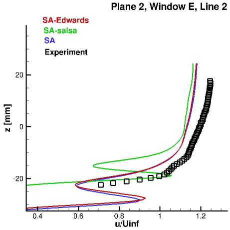
Velocity along the vertical lines

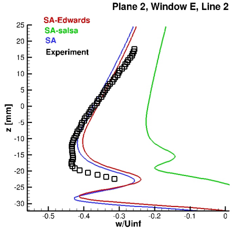


$alpha = 7deg$

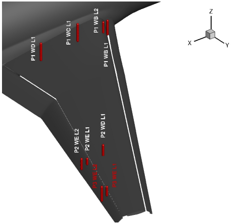




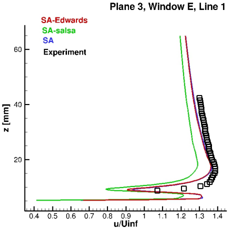


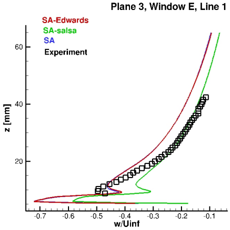


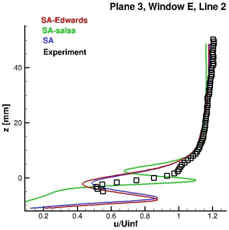
Velocity along the vertical lines

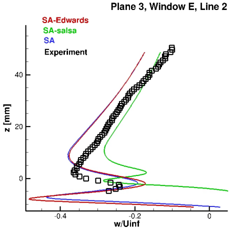


$alpha = 7deg$

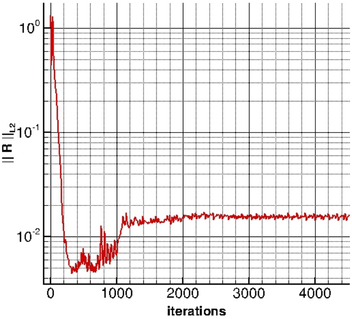


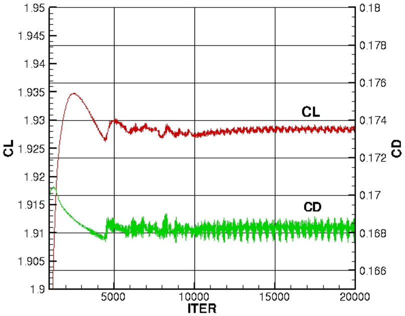






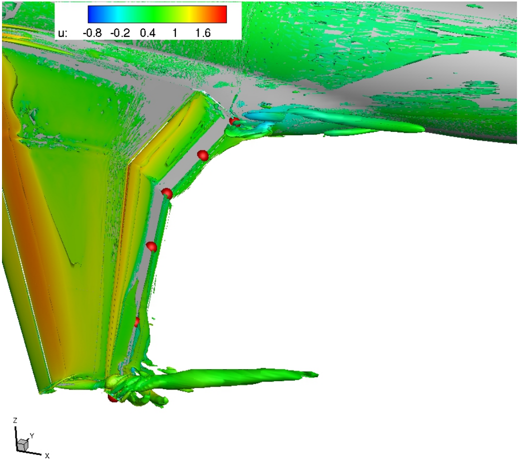
Convergence and coefficients evolution versus iterations





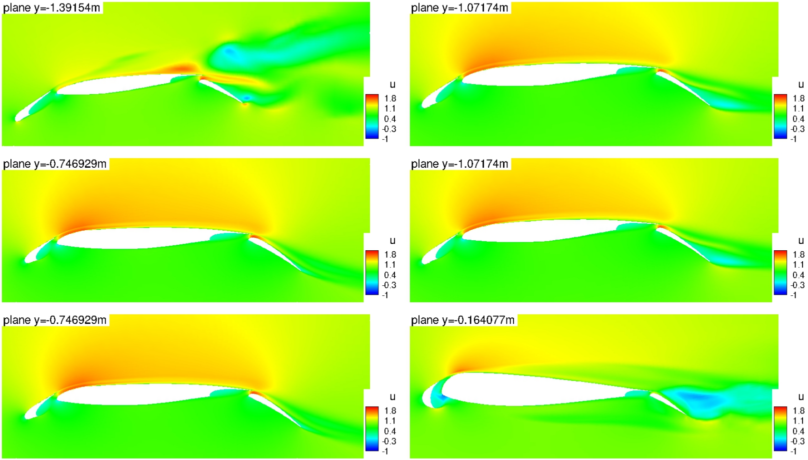
(SA-Edwards, $\alpha = 7deg$)

Unsteady flow



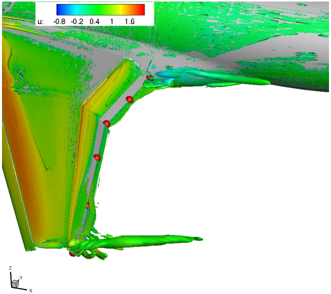
Isovalue of criteria λ_2=-2000, colored by U-velocity (SA-Edwards, $\alpha = 7$ [deg])

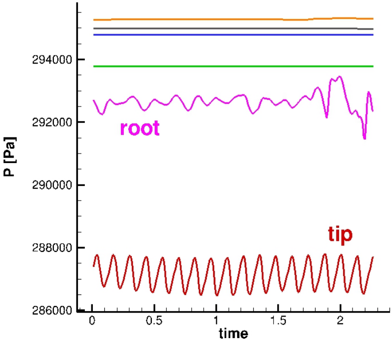
Streamwise velocity in the cross-sections of the wing (Y-plane)



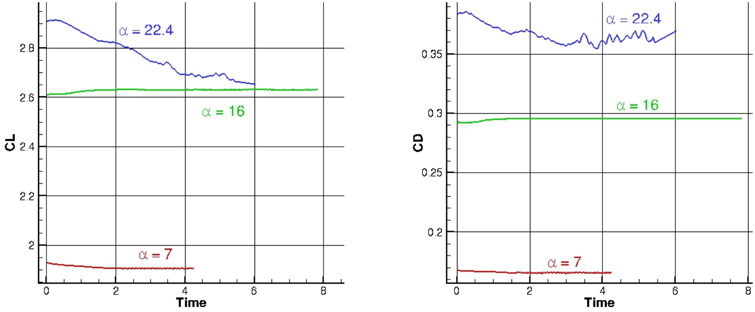
(SA-Edwards, $\alpha = 7$ [deg])

Time evolution of the pressure on 6 points on the flap



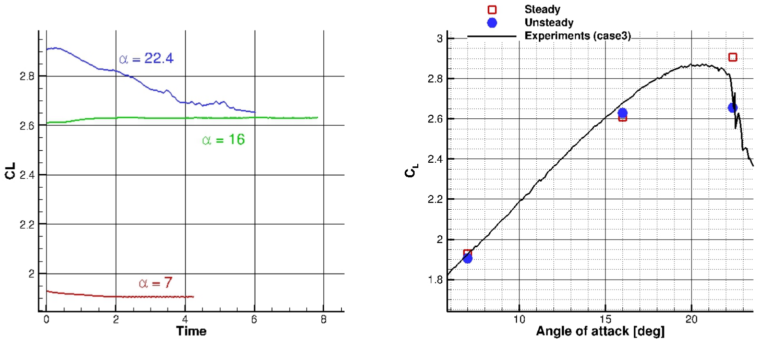


Steady versus unsteady results



(SA-Edwards)

Unsteady simulations (on medium grid)



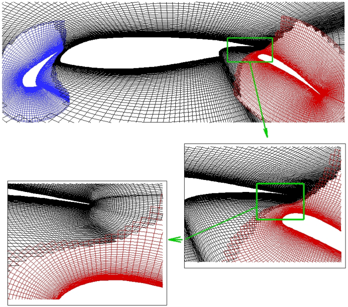
(SA-Edwards)

Conclusion

- Complex behavior of SA and SA-salsa versus angles of attack and grid size
- SA-Edouards less sensitive to the unsteady flow and grid size than SA and SA-salsa
- Moderate to high angles of attack need unsteady simulation
- Complex flows with different time/space scales
- Interaction between flap vortex shedding and tip vortex for low angle of attack

Outlook :

- Comparaison for unsteady simulation with time-average values
- To focus on the attraction of the vortex shedding by the tip vortex
- Simulation of the configuration with brackets, case 3 (need structured mesh)
- Simulation of the case 1 with overset grid and flap motion (need mesh)



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- Bombardier Aerospace
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CRIAQ/NSERC/Bombardier MDO-508 INTL

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Thank you for your attention

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Simulation : medium grid, SA, $\alpha = 22.4deg$